PRODUCTION OF SILICON SINGLE CRYSTAL AND SILICON SINGLE CRYSTAL WAFER

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Inventor(s): SAKURADA MASAHIRO; YANAGIMACHI TAKAHIRO; OTA TOMOHIKO

Applicant(s):: SHIN ETSU HANDOTAI CO LTD

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Abstract

PROBLEM TO BE SOLVED: To obtain a silicon single crystal wafer in which neither V-rich zone nor I-rich zone exists, having an extremely low defect de on the whole crystal surface from the whole single crystal bar by Czochralski method under readily controllable production conditions of wide control range.
SOLUTION: In growing a silicon single crystal by Czochralski method, in a defect distribution diagram showing a defect distribution when a pulling up speed is F [mm/min] and the average value of temperature gradient in the crystal in the pulling up axis direction between the melting point to 1,400 deg.C is shown by G [deg.C/mm], the horizontal axis is taken in the direction of a distance D [mm] from the crystal center to the circumference of the crystal and the vertical axis is taken in the direction of a value of F/G [mm<2> / deg.C.min], a crystal is pulled up in a range of an OSF zone OR and in a range of N-zone N outside the OSF zone. A silicon single crystal wafer which causes OSF or in which the nucleus of OSF exists and FPD and L/D do not exist in the whole face of the wafer when the central part of the wafer is subjected to thermal oxidation treatment is obtained.

DERWENT

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(71) **(71)[PATENTEE/ASSIGNEE]**

[ID CODE]

000190149

Shinetsu semiconductor K.K.

[ADDRESS]

Tokyo Chiyoda-ku Marunouchi 1-4-2

(72) **(72)[INVENTOR]**

Sakurada Masahiro

[ADDRESS]

Fukushima prefecture Nishishirakawa Saigo-mura Shinetsu semiconductor K.K. Shirakawa factory

(72) **(72)[INVENTOR]**

YANAGIMACHI, Takahiro

[ADDRESS]

Fukushima prefecture Nishishirakawa Saigo-mura Shinetsu semiconductor K.K. Shirakawa factory

(72) **(72)[INVENTOR]**

OTA, Tomohiko

[ADDRESS]
Fukushima prefecture Nishishirakawa Saigo-mura Shinetsu semiconductor K.K. Shirakawa factory

(74) **(74)[PATENT AGENT]**

[PATENT ATTORNEY]

YOSHINOMIYA, Mikio

(57) **(57)[SUMMARY]** (Amended)

[SUBJECT]
Control width is wide.
Under the manufacture conditions which are easy to control, the crystal whole surface where neither a V-rich area, nor an I-rich area exists is covered, and production of the silicon-single-crystal wafer by the CZ process which is an extremely low defect density is enabled with the entire single-crystal stick.

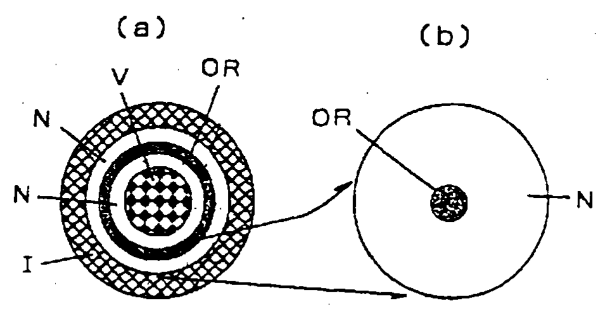
[SOLUTION]
Raising speed is set to F [mm/min] when

growing a silicon single crystal by the Czochralski method.

When you show the mean value of a gradient with G [degree C/mm] from the melting point of a silicon the crystal inside-temperature degree of the raising axial direction between 1400 degrees C, let distance D [mm] from a crystal centre to a crystal periphery be a horizontal axis.

In the defective distribution figure having shown the defective distribution, having made the value of F/G [mm2/ degree C*min] as the vertical axis, a crystal is pulled up within the limits of OSF area and N-area of that outer side.

And, when doing a heat oxidation treatment to the centre section of a wafer, OSF occurs or the nucleus of OSF exists. And, FPD and L/D obtain the silicon-single-crystal wafer which does not exist in a wafer whole surface.



[CLAIMS]

[CLAIM 1]

Raising speed is set to F [mm/min] when growing a silicon single crystal by the

Czochralski method. When you show the mean value of a gradient with G [degree C/mm] from the melting point of a silicon the crystal inside-temperature degree of the raising axial direction between 1400 degrees C, let distance D [mm] from a crystal centre to a crystal periphery be a horizontal axis. In the defective distribution figure having shown the defective distribution, having made the value of F/G [mm2/ degree C*min] as the vertical axis, a crystal is pulled up within the limits of OSF area and N-area of that outer side. The manufacturing method of a silicon single crystal characterised by the above-mentioned.

[CLAIM 2]

A crystal is pulled up mean-value G [degree C/mm] of a gradient as less than 3.0 [degree C/mm] the crystal inside-temperature degree of an above-mentioned raising axial direction.

The manufacturing method of a silicon single crystal described in Claim 1 characterised by the above-mentioned.

[CLAIM 3]

When the value of mean-value G [degree C/mm] of a gradient is shown with difference G= (Ge-Gc) with temperature-gradient Ge [degree C/mm] of the temperature gradient Gc of a crystal-centre part [degree C/mm], and a crystal periphery part the crystal inside-temperature degree of an above-mentioned raising axial direction, G pulls up a crystal less than as 1 degree C/mm. The manufacturing method of a silicon single crystal described in Claim 1 or Claim 2 characterised by the above-

mentioned.

[CLAIM 4]

When growing a silicon single crystal by the Czochralski method, OSF becomes as follows raising speed F [mm/min] to the disappearing critical speed in a crystal bulk centre.

A crystal is pulled up, controlling within (+/-)0.02 [mm/min].

The manufacturing method of a silicon single crystal characterised by the above-mentioned.

[CLAIM 5]

When growing a silicon single crystal by the Czochralski method, OSF becomes as follows the mean value of raising speed F [mm/min] to the mean value of the disappearing critical speed in a crystal bulk centre.

A crystal is pulled up, controlling within (+/-)0.01 [mm/min].

The manufacturing method of a silicon single crystal described in Claim 4 characterised by the above-mentioned.

[CLAIM 6]

A manufacturing method of a silicon single crystal, in which a crystal is pulled up in the manufacturing method of a silicon single crystal described in any 1 item of Claim 1 to Claim 5, applying a magnetic field during raising at silicon melt solution.

[CLAIM 7]

A manufacturing method of a silicon single crystal, in which let the magnetic field to apply be a horizontal magnetic field in the

manufacturing method of a silicon single crystal described in Claim 6.

[CLAIM 8]

A manufacturing method of a silicon single crystal, in which in the manufacturing method of a silicon single crystal described in Claim 6 or Claim 7, strength of the magnetic field to apply is made more than 2000G.

[CLAIM 9]

The silicon single crystal manufactured by the manufacturing method of the silicon single crystal of a description at Claim 1 or Claim 8.

[CLAIM 10]

A silicon-single-crystal wafer, in which when doing a heat oxidation treatment to the centre section of a wafer, in the silicon-single-crystal wafer grown by the Czochralski method, OSF occurs or the nucleus of OSF exists.

And, FPD and L/D do not exist in a wafer whole surface.

[CLAIM 11]

A silicon-single-crystal wafer, which is a silicon-single-crystal wafer described in Claim 10.

OSF area of an above-mentioned wafer centre section is the 5% or less of wafer area.

[CLAIM 12]

A silicon-single-crystal wafer, which is a silicon-single-crystal wafer described in Claim 10 or Claim 11.

OSF area of an above-mentioned wafer centre section is 20 mm or less in diameter.

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[CLAIM 13]

A silicon-single-crystal wafer, which is a silicon-single-crystal wafer described in any 1 item of Claim 10 or Claim 12.

OSF density which exists in an above-mentioned wafer centre section is less than 100 piece /cm2.

[CLAIM 14]

A silicon-single-crystal wafer, which is a silicon-single-crystal wafer described in any 1 item of Claim 10 or Claim 13.

The oxygen density of a wafer whole surface is 24 ppma or less.

[DETAILED DESCRIPTION OF INVENTION]

[0001]

[TECHNICAL FIELD]

This invention relates to the manufacturing method and the silicon-single-crystal wafer of the silicon single crystal with a little crystal defect.

[0002]

[PRIOR ART]

In recent years, the quality demand to the silicon single crystal produced by the Czochralski method (abbreviated to a CZ process hereafter) used as that substrate in

connection with the miniaturisation of the element accompanied by high integration of a semiconductor circuit has increased.

The defect of a single-crystal growth cause which worsens the oxide-film breakdown voltage characteristic especially called grown-in (Grown-in) defect of FPD, LSTD, and COP etc. and the characteristic of a device exists, and the reduction of that density and size is attached importance.

[0003]

It is related for explaining these defects.

First, the porosity type point defect called Vacancy (it may abbreviate with Vacancy and following V) received by the silicon single crystal, About the factor which determines each concentration of the interstitial silicon point defect called Interstitial -silicon (it may abbreviate with Interstitial-Si and following I) received, it explains being known in general.

[0004]

It leaves to a silicon single crystal and V area is Vacancy. It is an area with many things such as the recess generated from the insufficiency of a silicon atom in other words, and a hole.

I area is an area with many lumps of transition and the excessive silicon atom which are generated when a silicon atom exists too much.

And between V area and I area, atomic insufficiency and neutral (it may abbreviate with Neutral and following N) area without excess (little) will exist.

And, an above-mentioned grown-in defect (FPD, LSTD, COP etc) becomes as follows.

Anyway you look at it, when V and I are in supersaturating condition, it generates.

If it is less than a saturation even when there is deviation of some atoms, it has turned out that it does not exist as a defect.

[0005]

The concentration of this both point defect is decided from the relation of the raising speed (growth rate) of the crystal in a CZ process, and temperature-gradient G near the solid-liquid boundary surface in crystal.

Existence of the defect of the form of a ring called OSF (an oxidation induction stacking fault, Oxidation Induced Stacking Fault) near the boundary of V area and I area is confirmed.

[0006]

When categorising the defect of these crystal-growth cause and the diameter of a crystal is 6 inches, when a growth rate is comparatively as high-speed as the above appx. 0.6 mm/ min, the grown-in defect of FPD considered as the void cause to which porosity type point defects gathered, LSTD, and COP etc. exists with high density throughout the direction of the diameter of a crystal.

The area where these defect exists is called V-rich area (refer Figure 4 (a)).

[0007]

Moreover, when a growth rate is less than 0.6 mm/ min, in connection with a reduction of a growth rate, the above-mentioned OSF ring is generated from the periphery of a crystal.

The defect of L/D (the code address of the

transition loop between Large Dislocation: lattices, LSEPD, LFPD etc) considered to be the transition loop cause by the outer side of this ring exists in a low density.

The area where these defect exists is called I-rich area (refer Figure 4 (b)).

Furthermore, if a growth rate is made into a low speed less than 0.4 mm/ min back and front, OSF ring will condense and disappear to the centre of a wafer.

A whole surface is an I-rich area (Figure 4 (c)).

[0008]

Moreover, existence of the area where FPD, LSTD and COP of a porosity cause do not exist as for LSEPD of the a transition loop cause and LFPD, either recently called N area to the outer side of OSF ring in the middle of a V-rich area and an I-rich area is discovered (refer unexamined Japanese patent No. 8-330316).

This area is situated in the outer side of OSF ring.

And, an oxygen precipitation heat treatment is applied.

It is reported that it is the I-rich area side which is not rich (refer Figure 3 (a)) as when the contrast of precipitate is confirmed by X-ray observation etc., there is almost no oxygen precipitate and LSEPD and LFPD are formed.

[0009]

And, in conventional CZ raising machine, the temperature distribution in furnace of a raising machine is improved N area of a wafer which exists only in a very partial area.

Raising speed is adjusted.
F/G value (single crystal drawing speed is set to F [mm/min])
If it controls so the ratio expressed with F/G is 0.20-0.22 mm2 / degree C*min and a crystal is pulled up when setting the mean value of a gradient to G [degree C/mm] from the melting point of a silicon the crystal inside-temperature degree of the raising axial direction between 1300 degrees C, it is proposed that it is possible to extend N area to a wafer whole surface (refer Figure 3 (b)).

[0010]

[PROBLEM ADDRESSED]
However, if it is going to extend and manufacture such an extremely low defect area into the entire crystal, since this area will be limited only to N area by the side of an I-rich area, a control range is extremely narrow on manufacture conditions.

If it is experimental, in a production machine, a precision control is difficult at any rate.

It was impossible to have obtained a low defect crystal with the entire crystal stick only by manufacture being possible in a part of actual problem single-crystal stick. Therefore, productivity and a yield are extremely low. It is damage large to industrialisation. These inventors are the data for which did experiment and investigation and it obtained, in the defective distribution figure currently furthermore disclosed by this invention. Differing substantially was proved that it is the

produced defective distribution figure (figure 1 reference) which made data the group.

[0011]

This invention was formed in view of such a problem. Therefore, the width of a control is wide. Under the manufacture conditions which are easy to control, the crystal whole surface where neither a V-rich area, nor an I-rich area exists is covered, and production of the silicon-single-crystal wafer by the CZ process which is an extremely low defect density is enabled with the entire single-crystal stick. It aims at manufacturing, maintaining high-production property and a high yield.

[0012]

[SOLUTION OF THE INVENTION]

2 In order to achieve the above-mentioned objective, it succeeded in this invention, and when invention described in Claim 1 of this invention grows a silicon single crystal by the Czochralski method, it sets raising speed to F [mm/min]. When you show the mean value of a gradient with G [degree C/mm] from the melting point of a silicon the crystal inside-temperature degree of the raising axial direction between 1400 degrees C, let distance D [mm] from a crystal centre to a crystal periphery be a horizontal axis. In the defective distribution figure having shown the defective distribution, having made the value of F/G [mm2/ degree C*min] as the vertical axis, a crystal is pulled up within the limits of OSF area and N-area of that

outer side. It is the manufacturing method of the silicon single crystal which is characterised by the above-mentioned.

[0013]
It is the defective distribution figure of Figure 1 which analysed and required the result of experiment and investigation in this way the OSF area (it is a usual ring shape) to a group.
However, if a crystal is pulled up within the limits of N-area of that outer side as it being centre, and forming in the shape of a round if FPD etc. disappears, a control range will spread.
FPD and L/D can produce easily the silicon-single-crystal wafer which does not exist in a wafer whole surface.
And, OSF area which exists in a centre section is an extremely small area to a wafer whole-surface product. The influence on a device yield is able to be slight.

[0014]
That is, the silicon single crystal which can be pulled up by this invention has contained the area which may generate OSF at the time of a heat oxidation treatment.
However, as N area outside OSF ring is enlarged upper limit, it is pulled up. Therefore, raising speed and the control range of the temperature gradient in a crystal are wide.
Also in a common production machine, manufacture condition setting becomes simple.
The wafer with many N areas is simply producible.

[0015]

In this case, as more illustrative conditions, as described in Claim 2, a crystal is pulled up mean-value G [degree C/mm] of a gradient as less than 3.0 [degree C/mm] the crystal inside-temperature degree of a raising axial direction.

Moreover as described in Claim 3, when the value of mean-value G [degree C/mm] of a gradient is shown with difference G= (Ge-Gc) with temperature-gradient Ge [degree C/mm] of the temperature gradient Gc of a crystal-centre part [degree C/mm], and a crystal periphery part the crystal inside-temperature degree of a raising axial direction, G pulls up a crystal less than as 1 degree C/mm.

[0016]

Although OSF area is situated in a centre section by considering as such raising conditions, the silicon single crystal to which neither FPD, nor L/D exists in a wafer whole surface is raisable.

[0017]

Next, when invention described in Claim 4 of this invention grows a silicon single crystal by the Czochralski method, raising speed F [mm/min] to the critical speed to which OSF disappears in a crystal bulk centre, a crystal is pulled up, controlling within (+/-)0.02 [mm/min].

It is the manufacturing method of the silicon single crystal which is characterised by the above-mentioned.

[0018]

Thus, OSF becomes as follows raising speed F

[mm/min] to the critical speed which disappears in a crystal bulk centre.

If the crystal was pulled up, controlling within (+/-)0.02 [mm/min], the area which may generate OSF at the time of a heat oxidation treatment has been included.

However, the silicon single crystal which enlarged N area of OSF outer side upper limit and to which neither FPD, nor L/D exists in a wafer whole surface is raisable.

Moreover raising speed is only controlled accurately. Therefore, also in a common production machine, it can correspond sufficiently.

[0019]

And, as described in Claim 5, when growing a silicon single crystal by the Czochralski method, OSF becomes as follows the mean value of raising speed F [mm/min] to the mean value of the critical speed which disappears in a crystal bulk centre. If a crystal is pulled up, controlling within (+/-)0.01 [mm/min], in one entire crystal stick, the silicon single crystal which enlarged N area of OSF outer side upper limit and to which neither FPD, nor L/D exists in a wafer whole surface is raisable.

[0020]

Moreover, it is preferable to pull up a crystal, applying a magnetic field to silicon melt solution during raising, as this invention was described in Claim 6.

By applying a magnetic field, the convection current in silicon melt solution is suppressed.

It becomes simple to control on the raising

conditions of above-mentioned Claim 1 - Claim 5.

[0021]

As especially described in Claim 7, let the magnetic field to apply be a horizontal magnetic field. Moreover, as described in Claim 8, it is preferable to make strength of the magnetic field to apply more than 2000G.

Gradient G and difference G of the temperature gradient which comes out in the surface are made small a crystal inside-temperature degree. In order to extend N area in crystal, the horizontal magnetic field is more preferable. If it is less than 2000G, a magnetic-field impression effect is little.

[0022]

And, when the silicon single crystal manufactured by above-mentioned Claim 1 or above-mentioned Claim 8 by the manufacturing method of the silicon single crystal of a description does a heat oxidation treatment to the centre section of a crystal bulk, OSF occurs or the nucleus of OSF exists.

And, FPD and L/D can obtain that which does not exist in a crystal (Claim 9).

Therefore, when the silicon-single-crystal wafer which slices such a silicon single crystal and is obtained does a heat oxidation treatment to the centre section of a wafer such as Claim 10, OSF occurs or the nucleus of OSF exists.

And, FPD and L/D are the silicon-single-crystal wafer which does not exist in a wafer whole surface.

DERWENT

[0023]

That is, when the silicon-single-crystal wafer of this invention does the wafer a heat oxidation treatment, OSF is generated in the wafer centre section.

Or the nucleus of OSF is latent.

However, as FPD and L/D (LSEPD, LFPD) are the wafers of not existing in a wafer whole surface and it was shown in Figure 2 (b), a V-rich area or I-rich area does not exist in the so-called wafer whole surface, either. The area of neutral N area is extremely large.

The nucleus of OSF is latent in the silicon-single-crystal wafer of large this invention of such an N area.

When doing the heat oxidation treatment of the wafer, OSF area which OSF may generate exists in a centre section.

However, that area is suppressed upper limit in the wafer centre section.

It is a wafer with the novel defective structure to which N area of OSF outer side was meanwhile enlarged fully.

[0024]

In this way OSF area of a wafer centre section is the 5% or less of wafer area, for example, (Claim 11), or OSF area of a wafer centre section can do the silicon-single-crystal wafer obtained in diameter of 20 mm or less (Claim 12).

Therefore, the ratio of OSF area to the whole-surface product of a wafer is small.

Since the area of N area is large, it becomes the silicon-single-crystal wafer which can improve a device yield.

[0025]

2 And, as described in Claim 13, with the silicon-single-crystal wafer of this invention, OSF density which exists in a wafer centre section can be made less than into 100 piece /cm2.

As especially described in Claim 14, the potential nucleus of OSF exists the oxygen density of a wafer whole surface by the oxygen precipitation heat treatment less than 24 ppma (ASTM'79 value) then.

However, when doing OSF heat oxidation treatment, OSF can be considered as the silicon-single-crystal wafer with which it does not generate and FPD and L/D do not exist in a wafer whole surface.

[0026]

Thus, if the oxygen density in a growth crystal is restrained to 24 ppma or less, the growth of OSF nucleus can be inhibited.

Since a device is not substantially affected even when the potential nucleus of OSF or OSF exists in a wafer, when doing OSF heat oxidation treatment, the nucleus of OSF is latent in the wafer eventually.

However, OSF is not generated and it is mentioned that FPD and L/D (LSEPD, LFPD) do not exist in a wafer whole surface, either. The wafer of the useable extremely low defect density of the whole surface where OSF to which the so-called wafer whole surface also affects a V-rich area and an I-rich area damage does not exist, either can be obtained.

And it is possible to also make a control of F/G into a broad control range as mentioned

above in this case.

A wafer is easily producible on industry.

[0027]

Hereafter, it explains to a detail for every this 227 invention. However, this invention is not limited to these. In advance of explanation, it explains previously for every of each vocabulary.

1) Cut down a wafer from the silicon-single-crystal stick after the growth in FPD (Flow Pattern Defect).

After etching and removing a surface distortion layer with the mixed-solution of a hydrofluoric acid and nitric acid, a pit and a ripples pattern occur by etching the surface with the mixed-solution of $K_2 Cr_2 O_7$, a hydrofluoric acid, and water (Secco etching).

This ripples pattern is called FPD.

The defect of an oxide-film breakdown voltage increases (refer unexamined-Japanese-patent-No. 4-192345 gazette) as FPD density in a wafer surface is high.

[0028]

2) With SEPD (Secco Etch Pit Defect), when applying FPD and identical Secco etching, they are FPD and a call the thing accompanied by a flow mark (flow pattern). The thing accompanied by a flow mark is called SEPD.

It is considered that large SEPD (LSEPD) 10 micrometers or more originates in the transition cluster in this.

When the transition cluster exists in a device, electricity leaks through this transition.

It stops achieving function as P-N junction.

[0029]

3) Cut down a wafer from the silicon-single-crystal stick after the growth with LSTD (Laser Scattering Tomography Defect).

A wafer is opened after etching and removing a surface distortion layer with the mixed-solution of a hydrofluoric acid and nitric acid.

An infrared-light is projected from this cleavage plane. The scattered light by the defect which exists in a wafer by detecting the light which came out from the wafer surface is detectable.

About the scattering body observed here, it is an academy etc., and there is already a report.

It is regarded as oxygen deposit (J. J.A.P.Vol.32, P3679, 1993 reference).

Moreover, the result referred to as being the void (hole) of an octahedron is also reported by the recent study.

[0030]

4222 4) In COP (Crystal Originated Particle), it is the defect which degrades the oxide-film breakdown voltage of the central part of a wafer and which causes. The defect made to FPD in Secco etch works as selecting etching liquid in ammonia hydrogen-peroxide-solution washing (washing by the mixed-solution of $NH_4OH:H_2O_2:H_2O=1:1\text{-}2:5\text{-}7$).

It is made to COP.

The diameter of this pit is investigated by the light scattering measurement by 1 micrometer or less.

[0031]

5) There are LSEPD and LFPD etc. in L/D (code address of the transition loop between

Large Dislocation: lattices).

It is the defect considered to be the transition loop cause.

A large thing 10 micrometers or more is mentioned that LSEPD described above also in SEPD.

Moreover, LFPD mentions the large thing of the above-mentioned FPD whose size of an end pit is 10 micrometers or more among them.

The transition loop cause is considered also here.

[0032]

These inventors become as follows about the silicon single crystal growth by the CZ process, as beforehand proposed by Japanese Patent Application No. 9-199415.

When investigated in detail about the boundary neighbourhood of V area and I area, the number of FPD, LSTD, and COP was remarkably little to the extremely narrow area of this boundary neighbourhood, and it discovered that there was a neutral area where LSEPD does not exist, either.

[0033]

Then, when this neutral area could be extended to the wafer whole surface, it was conceived that a point defect could be reduced substantially. And, among the wafer surfaces of a crystal, since it is substantially fixed, raising speed becomes as follows in the relation between a growth rate (raising speed) and a temperature gradient. The main factors which determine a concentration distribution of an in-plane point defect are temperature gradients. In

other words, among wafer surfaces, if that a difference is in the temperature gradient of an axial direction can reduce this difference on a problem, it will discover that the concentration difference of the point defect in a wafer surface can also be reduced. When temperature in the furnace was controlled and the difference of the temperature gradient Gc of a crystal-centre part and temperature-gradient Ge of a crystal periphery part was pulled up so that it might be made to G=(Ge-Gc) =<0.5 degree-C/mm, and speed was adjusted, the wafer without the defect which a wafer whole surface becomes from N area came to be obtained.

[0034]

With this invention, difference G of the aforementioned temperature gradients is used the crystal drawing apparatus by the small CZ process. Raising speed was changed and the inside of a crystal plane was investigated.

The defective distribution figure which is newly shown in Figure 1 as a result was able to be obtained.

N area which exists between a V-rich area and an I-rich area was conventionally considered to be only the outer side of OSF ring (nucleus).

However, it confirmed that N area existed also inside OSF ring (refer Figure 2 (a)).

That is, in above-mentioned Japanese Patent Application No. 9-199415, OSF ring had become the V-rich area and the boundary area of N area (refer Figure 3 (a)). However, it was found that these two are not necessarily congruous. When experimenting with the

crystal drawing large apparatus of conventional G, this is not discovered but investigated the crystal which was used the small crystal drawing apparatus of G of this time above.
As a result, it was discovered.

[0035]
However, a control range is narrow when only N area of this OSF ring outer side tends to pull up a crystal only in N area of OSF ring inner side.
It is difficult to consider as N area with the entire single-crystal stick.
A yield and productivity are low.
The same problem as an above-mentioned PRIOR ART of not being preferable is generated on industrial production.

[0036]
Then, these inventors inquired on the basis of Figure 1. As a result, mass-production property is considered by the CZ process.
As quality producible with the entire crystal stick, OSF is distributed over the bulk centre section of a crystal stick.
The size of that area is suppressed upper limit.
It conceives of pulling up the residue a crystal as an N area of OSF ring outer side.
This invention is completed.
That is, if it mentions in the defective distribution figure of Figure 1, it is pulling up a crystal within the limits of OSF area and N-area of that outer side.

[0037]
Thus, if a crystal is pulled up within the limits of

OSF area and N-area of that outer side to a group, a control range will spread the defective distribution figure of Figure 1 which analysed and required the result of experiment and investigation.

FPD and L/D can produce easily the silicon single crystal and the wafer which do not exist in a wafer whole surface.

And, OSF area which exists in a centre section is an extremely small area to a wafer whole-surface product.

The influence on a device yield is slight and is managed.

[0038]

In this case, pulling up a crystal in OSF ring and N area of that inner side is also thought of.

However, an inner side is N area and, as for the wafer made, an outer side is OSF area.

Since OSF area becomes broad relatively, it is not preferable.

[0039]

And, OSF area is in above-mentioned this invention at such an in-crystal centre.

That outer side was used comprehensive heat-transfer analysis soft(ware) FEMAG (F. Dupret, P.Nicodeme, Y.Ryckmans, P.Wouters, and M.J.Crochet, Int.J.Heat Mass Transfer, 33, 1849 (1990)), and analysed keenly temperature of the raising apparatus used as N area in the furnace.

[0040]

As a result, mean-value G [degree C/mm] of a gradient was indicated that what is sufficient is

just to pull up a crystal as less than 3.0 [degree C/mm] the crystal inside-temperature degree of a raising axial direction.

Moreover, the value of mean-value G [degree C/mm] of a gradient was indicated that G should just pull up a crystal less than as 1 degree C/mm about difference G= (Ge-Gc) with temperature-gradient Ge [degree C/mm] of the temperature gradient Gc of a crystal-centre part [degree C/mm], and a crystal periphery part the crystal inside-temperature degree of a raising axial direction.

This value tends to control markedly the crystal whole surface proposed beforehand compared with G=(Ge-Gc) =<0.5 degree-C/mm which is the conditions for considering as N area. There is mass-production property.

[0041]

Although OSF occurs or the nucleus of OSF exists when doing a heat oxidation treatment to a crystal centre section by growing a single crystal on such raising conditions, FPD and L/D can obtain the silicon single crystal which does not exist in a crystal.

Therefore, the silicon-single-crystal wafer which slices such a silicon single crystal and is obtained makes the silicon-single-crystal wafer with which FPD and L/D do not exist in a wafer whole surface, while OSF occurs or the nucleus of OSF exists, when doing a heat oxidation treatment to the centre section of a wafer.

[0042]

That is, when the silicon-single-crystal wafer of this invention does the wafer a heat oxidation

treatment, OSF is generated in the wafer centre section.

Or the nucleus of OSF is latent.

However, as FPD and L/D (LSEPD, LFPD) are the wafers of not existing in a wafer whole surface and it was shown in Figure 2 (b), a V-rich area and an I-rich area do not exist in the so-called wafer whole surface. The area of neutral N area is extremely large.

The nucleus of OSF is latent in the silicon-single-crystal wafer of large this invention of such an N area.

When doing the heat oxidation treatment of the wafer, OSF area which OSF may generate exists in a centre section.

However, that area is suppressed upper limit in the wafer centre section.

It is a wafer with the novel defective structure where N area of OSF outer side was meanwhile enlarged fully.

[0043]

In this case, if it is originally, an I-rich area will be formed on the outer-side area of OSF.

L/D should occur in that area.

However, in the single-crystal manufacturing method of this invention, mean-value G [degree C/mm] of a gradient is made less than into 3.0 [degree C/mm] the crystal inside-temperature degree of a raising axial direction as mentioned above.

Moreover, about difference G= (Ge-Gc) with temperature-gradient Ge [degree C/mm] of the temperature gradient Gc of a crystal-centre part [degree C/mm], and a crystal periphery part, G becomes as follows the value of mean-value G

[degree C/mm] of a gradient less than as 1 degree C/mm the crystal inside-temperature degree of a raising axial direction. Since the crystal is pulled up, N area of OSF ring outer side spreads. An I-rich area is not formed.

[0044]

And, OSF makes it grow near the critical speed which disappears in the crystal centre section, at the time of a silicon single crystal growth.

If you are made to make the size of OSF area of a centre section as small as possible, let OSF area when considering as a silicon-single-crystal wafer be the 5% or less of wafer area, for example.

Or OSF area of a wafer centre section can do in diameter of 20 mm or less.

Therefore, the ratio of OSF area to the whole-surface product of a wafer is small.

Since the area of N area which neither FPD, nor L/D has is large, it becomes the silicon-single-crystal wafer which can improve a device yield.

[0045]

2 And, OSF makes it grow as mentioned above also with OSF area of a centre section near the critical speed which disappears in the crystal centre section, at the time of a silicon single crystal growth.

If the size of OSF area of a centre section becomes small as much as possible, OSF density which exists in a wafer centre section can be done to less than 100 piece /cm2.

It might be substantially made to 0.

Therefore, also let influence on the yield in a

device process be a not so large thing.

[0046]

It turns out that OSF ring is not generated by heat oxidation treatment even when the nucleus of OSF ring exists in a wafer whole surface from the recent study in the case of a low-oxygen concentration, and a device meanwhile is not affected about OSF ring.

The limitation value of this oxygen density is used identical crystal drawing apparatus.

The crystal of some kinds of oxygen-density levels was pulled up.

As a result, if the oxygen density in a wafer whole surface is 24 ppma or less, when performing a heat oxidation treatment of a wafer, it is confirmed that OSF ring is not generated.

[0047]

That is, when Figure 5 pulls up the crystal of one and an oxygen density is gradually lowered to inside, the nucleus which is OSF covering crystal full length exists.

However, when performing a heat oxidation treatment of a wafer, it is that OSF ring is observed to 24 ppma, and OSF ring nucleus exists in 24 ppma or less.

However, it means that OSF ring by heat oxidation treatment is not generated.

[0048]

What is sufficient is just incidentally, to perform by the method conventionally employed generally, in order to set the oxygen density during growth crystal to 24 ppma or less.

For example, means to adjust a distribution, an atmosphere pressure, the amount of gas flows, etc. a crucible rotating-speed or melt-solution inside-temperature degree can perform simply.

[0049]
Therefore, the growth of OSF nucleus which exists the oxygen density of a wafer whole surface in less than 24 ppma (ASTM'79 value), then a centre section can be inhibited also with this invention.
Since a device is not substantially affected even when the potential nucleus of OSF or OSF exists in a wafer, when doing OSF heat oxidation treatment, the nucleus of OSF is latent in the wafer eventually.
However, OSF is not generated and it is mentioned that FPD and L/D (LSEPD, LFPD) do not exist in a wafer whole surface, either. The wafer of the extremely low defect density with the useable whole surface where OSF to which the so-called wafer whole surface also affects a V-rich area and an I-rich area damage does not exist, either can be obtained.

[0050]

[Embodiment]
Hereafter, the embodiment of this invention is explained in detail, referring drawing.
First, Figure 6 explains the example of composition of the single crystal drawing apparatus by the CZ process which is used with this invention.

As shown in Figure 6, this single crystal drawing equipment 30 becomes as follows. Raising chamber 31, the crucible 32 provided in the raising chamber 31, the heater 34 arranged on the perimeter of a crucible 32, the crucible hold axis 33 which makes a crucible 32 rotate, and its rotating mechanism (not illustrated), the seed chuck 6 which maintains the seed crystal 5 of a single-crystal silicon, the wire 7 which pulls up the seed chuck 6, It has these and the coiling device (not illustrated) which rotates or rolls a wire 7 up, and it is comprised.

A quartz crucible is provided in the side in which a crucible 32 accommodates silicon melt solution (hot water) 2 of that inner side.

The graphite crucible is provided in that outer side. Moreover, the heat insulating material 35 is arranged on the perimeter of an outer side of a heater 34.

[0051]

Moreover, in order to satisfy manufacture conditions, such as a gradient, the crystal inside-temperature degree in connection with the manufacturing method of this invention, the annular solid-liquid boundary-surface heat insulating material 8 is provided in the periphery of the solid-liquid boundary surface of a crystal.

The upper-part surrounding heat insulating material 9 is arranged on that.

This solid-liquid boundary-surface heat insulating material 8 provides the 3-5 cm gap 10 between that lower end and the molten metal surface water of the silicon melt solution 2, and is installed. The upper-part surrounding

heat insulating material 9 may not be used according to conditions. Furthermore, cooling gas is sprayed. Moreover, the cylindrical cooling system 36 which interrupts a radiant heat and cools a single crystal is provided.

Moreover, in this embodiment, the magnet 37 which becomes the horizontal outer side of the raising chamber 31, for example, from a superconductive coil etc. is installed.

The convection current of melt solution is suppressed by applying a magnetic field horizontal to the silicon melt solution 2.

The so-called MCZ method which aims at the stable growth of a single crystal is employed.

[0052]

In this case, as shown in Figure 6, in the periphery space of the crystal-growth boundary surface in the single-crystal stick 1 on the molten metal surface water of the raising chamber 31 (solid-liquid boundary surface 4), that it is important especially for satisfying the conditions of this invention, the temperature of the crystal near the molten metal surface water is having provided the annular solid-liquid boundary-surface heat insulating material 8 in the temperature region from 1420 degrees C to 1400 degrees C, the thing which the upper-part surrounding heat insulating material's 9 was arranged on that, and having arranged the magnet 37 on the outer side of the raising chamber 31. By this, mean-value G of a gradient can be made less than into 3.0 [degree C/mm] a crystal inside-temperature degree.

And, raising speed is stabilised while enabling

pulling up a crystal, making difference G= (Ge-Gc) with temperature-gradient Ge [degree C/mm] of the temperature gradient Gc of a crystal-centre part [degree C/mm], and a crystal periphery part less than as 1 degree C/mm. A high-precision control can be enabled.

Furthermore, the equipment 36 which cools a crystal, for example, cooling system, is provided in the upper part of this heat insulating material depending on necessity.

Cooling gas shall be sprayed on this from the upper part, and a crystal shall be cooled.

It is sufficient also as structure which attached the radiant-heat reflecting plate in the tube lower part.

[0053]

Thus predetermined gap is provided in the position on direct of a Liquid surface, and a heat insulating material is arranged on it.

Furthermore by considering as the structure which provided the apparatus which cools a crystal in the upper part of this heat insulating material, a heat-retention effect is obtained by the radiant heat near the crystal-growth boundary surface.

Since the radiant heat from a heater etc. can be cut, the manufacture conditions of this invention can be satisfied in the upper part of a crystal. As a cooling system of this crystal, the air-cooling duct, the water-cooling coil, etc. which surround the perimeter of a crystal are provided particularly, and it may be made to secure a desired temperature gradient in the above-mentioned cylindrical cooling system 36.

[0054]
Next, the single-crystal cultivation method by the above-mentioned single crystal drawing equipment 30 is explained.

First, the high-purity polycrystal raw material of a silicon is heated and fused in a crucible 32 more than a melting point (about 1420 degrees C).

Next, the surface abridging central part of melt solution 2 is made to contact or immerse the end of a seed crystal 5 by starting rolling a wire 7. Then, a single crystal growth is started by rolling up, making a wire 7 rotate, while making the crucible hold axis 33 rotate in the suitable direction, and pulling up a seed crystal 5. Henceforth, the single-crystal stick 1 of a substantially cylinder shape can be obtained by adjusting raising speed and temperature appropriately.

[0055]
And, the inside of a single-crystal stick growth needs to control that diameter to desire value.

Then the inside which is a crystal pull-up measures the diameter of a crystal stick from the window provided, for example, in the raising chamber 31 using CCD camera etc.

Measurement of a diameter observes near the crystal-growth boundary surface with above-mentioned CCD camera etc.

The bright part called fusion ring which exists in the boundary part of silicon melt solution and a crystal is detected from a quantity-of-light signal. It is performed by specifying that position.

[0056]

The obtained diameter data are inputted into CPU of the computer attached to the raising apparatus.

The error with a target diameter is calculated.

Feedback controls, such as sending the voltage signal which is equivalent to the temperature regulator which controls a heater 34, and the raising speed adjustment device of a wire 7 at that correctioning amount, are performed automatically.

That is, the temperature and a crystal drawing speed of silicon melt solution are controlled by controlling the rotating speed of the motor which rolls and raises the output and the wire 7 of a heater 34.

And, since this diameter control may do the reduction of that error, the correctioning amount of temperature and raising speed is computed by PID calculating system etc.

In this way, 1 single-crystal stick is grown, whilst controlling diameter.

[0057]

And, OSF is a crystal bulk centre and crystal drawing speed F [mm/min] is controlled by this invention to pull up near the disappearing critical speed.

While there is that no V area which FPD etc. generates in the crystal centre section is formed by this, OSF area can be made small as much as possible.

An important thing is controlling crystal drawing speed accurately within fixed limits to a critical speed here.

[0058]

That is, in an above-mentioned defective distribution figure, a crystal is pulled up as within the limits of OSF area and N-area of that outer side such as this invention.

When doing a heat oxidation treatment to the centre section of a wafer, it has OSF area. It is necessary to pull up a crystal, controlling raising speed of a crystal within (+/-)0.02 [mm/min] to a critical speed, in order for FPD and L/D of the very thing to obtain that which does not exist in a wafer whole surface.

[0059]

Then, with this invention, it was performed that it pulls up and making high precision of a speed control is attained.

Though any system could perform making high precision of raising speed, it corresponded by enhancing the response of a feedback control in an above-mentioned diameter control here.

[0060]

That is, a feedback control averages the diameter data detected in a certain fixed time.

This is transmitted to CPU.

The deviation with a setting diameter is computed.

It is the structure which repeats control of outputting that correctioning amount.

However, the time which detects and averages this diameter data is shortened, and the cycle of a feedback is brought forward (for example, 60 seconds is made into 30 seconds).

The response was enhanced. Especially, the

response to an adjustment type is made quick. It was made to suppress the fluctuation of a rate of crystal growth (raising speed) fully. According to such a method, it is only to alter 1 setting of a feedback control. Therefore, also in a common production machine, it can correspond sufficiently. It is simple.

[0061]
And, if the aforementioned controls are performed when growing a silicon single crystal by the Czochralski method, it will become desired quality about the region to which the above-mentioned control was performed among crystal sticks.
However, the entire crystal stick becomes as follows as that which has the quality of this invention. In order to improve a yield, OSF becomes as follows the mean value of raising speed F [mm/min] to the mean value of the disappearing critical speed in a crystal bulk centre. It needs to be made to pull up a crystal, controlling within (+/-)0.01 [mm/min].

[0062]
In this case, in an above-mentioned defective distribution figure, it considers as within the limits of OSF area and N-area of that outer side accurately.
Moreover, raising speed of a crystal is controlled within (+/-)0.02 [mm/min] to a critical speed.
Or, OSF becomes as follows the mean value of raising speed to the mean value of the critical speed which disappears in a crystal bulk centre. It is preferable to pull up a crystal,

applying a magnetic field to silicon melt solution during raising in addition to improvement of the response of an above-mentioned feedback control, in order to do to less than (+/-)0.01 [mm/min]. By applying a magnetic field, the convection current in silicon melt solution is suppressed. Since it becomes simple to control on above-mentioned raising conditions more, it becomes easy make the entire crystal stick into desired quality.

[0063]

Let the magnetic field applied especially be a horizontal magnetic field.

Moreover, it is strength of the magnetic field to apply more than 2000G. It is sufficient to do to more than 3000G more preferably.

The convection current of silicon melt solution is suppressed. Though the so-called vertical magnetic field or a cusp magnetic field may be applied in order to stabilise raising speed, gradient G and difference G of an in-plane temperature gradient are made small a crystal inside-temperature degree. In order to extend N area in crystal, the horizontal magnetic field which a magnetic field effects horizontally to a crystal-growth boundary surface is more preferable. Moreover, since its convection inhibitory effect is stronger as the magnetic field intensity to apply is strong, though it is sufficient, if it has 8000G, it is enough. Conversely, if it is less than 2000G, a magnetic-field impression effect will decrease. The stabilisation effect of raising speed becomes small.

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[0064]

In this way, a magnetic field is applied more than 4000G.

Raising speed of a crystal is made high precision.

It controls within (+/-)0.02 [mm/min] to a critical speed. If raising speed is stabilised extremely and a crystal is pulled up as less than (+/-)0.01 [mm/min] to the mean value of the critical speed to which OSF disappears the mean value of raising speed in a crystal bulk centre, OSF of a single-crystal centre section will be a low density extremely. It may scarcely generate.

[0065]

[Example]

Hereafter, an Example is given and the illustrative embodiment of this invention is explained. However, this invention is not limited to these. With the raising apparatus which was shown in Figure 6 and in which horizontal magnetic-field impression is possible, 100kg charge of the raw-material polycrystal silicon is done to a 25 inch quartz crucible. The diameter of 8 inches, the bearing <100>, and about 1m silicon-single-crystal stick of the length of a straight body part were pulled up.

The hot-water temperature of silicon melt solution makes 4 cm space the lower end of an annular solid-liquid boundary-surface heat insulating material from about 1420 degrees C and molten metal surface water.

The cyclic solid-liquid boundary-surface heat

insulating material of 10 cm height and the upper-part surrounding heat insulating material of 30 cm height were arranged on that.

[0066]

On this condition, mean raising speed is changed to 0.8-0.3 mm/ min, and a crystal is pulled up. When OSF investigates the critical speed which disappears in a crystal bulk centre, it is 0.50 mm/ min in the shoulder part of a single-crystal stick.

It was 0.45 mm/ min in the termination part of a straight barrel.

Therefore, it made pulling up a crystal, making this critical raising speed as target raising speed.

[0067]

The obtained single-crystal stick is made into slivers in the direction of a crystal growth.

2 samples with a thickness of 2 mm are cut out.

The mirror-surface process was applied to that surface.

After 1 of sheets of that applied Secco etching for 30 minutes, they measured grown-in defects, such as FPD and L/D, by doing a microscope observation. About the 1 remaining sheet, an atmosphere (water vapour + oxygen) and the heat oxidation treatment for 1200 degree-C / 100 minutes are applied. It observes by the X-ray topograph. Generating situations, such as OSF ring, were confirmed.

[0068]

(Example 1) An impression magnetic field intensity is set to 0.

A response is enhanced the cycle of the feedback of a diameter control as 30 seconds from 60 conventional seconds.

It is made to suppress the fluctuation of a rate of crystal growth (raising speed) fully.

The crystal was pulled up, controlling so OSF becomes the raising speed of a crystal less than (+/-)0.02 [mm/min] to the critical speed which disappears in a crystal bulk centre.

[0069]

The control result of the rate of crystal growth (raising speed) of the crystal stick which could be done, and the result of the defective generating situation in a crystal stick were shown in Figure 7. Figure 7 (a) is a figure as a result of a growth rate. Figure 7 (b) is a figure as a result of a crystal defect.

[0070]

The part (A area in a figure) into which the control is performed so that it may become the raising speed of a crystal less than (+/-)0.02 [mm/min] to a critical speed if this result is observed is the crystal of the desired quality of this invention.

That is, while OSF area is situated in a crystal centre section, it turns out that it becomes that to which FPD and L/D do not exist in a crystal.

Meanwhile, upwards, FPD area is formed by the crystal centre section in the part shifted in the raising speed conditions of above-mentioned this invention (B area in a figure), and L/D area is conversely formed in the part which shifted the raising speed conditions of this invention downward (C area in a figure).

And, N area which is a defect-free area between OSF area and L/D area is formed with part single-crystal stick.

Thus, in Example 1, the crystal of only the quality of this invention or N area was able to obtain by about 40-50-% region of a single-crystal stick.

[0071]

(Example 2) An impression magnetic field intensity is set to 4000G.

A response is enhanced the cycle of the feedback of a diameter control as 30 seconds from 60 conventional seconds.

It is made to suppress the fluctuation of a rate of crystal growth (raising speed) fully.

The crystal was pulled up, controlling so OSF becomes the mean value of the raising speed of a crystal less than (+/-)0.02 [mm/min] to the critical speed which disappears in a crystal bulk centre.

[0072]

The control result of the rate of crystal growth (raising speed) of the crystal stick which could be done, and the result of the defective generating situation in a crystal stick were shown in Figure 8. Figure 8 (a) is a figure as a result of a growth rate. Figure 8 (b) is a figure as a result of a crystal defect.

[0073]

If this result is observed, it will pull up by applying a magnetic field, and speed will be stabilised.

The raising speed of a crystal is indicated that a

control is performed so that it may become less than (+/-)0.02 [mm/min] to a critical speed by almost all regions.

While OSF area was situated, the crystal, i.e., crystal centre section, of desired quality of this invention, the region (A area in a figure) used as that to which FPD and L/D do not exist in a crystal was able to obtain by about 80-% region of a single-crystal stick.

[0074]

Meanwhile, in a partial region, there is still a part which does not comprise quality of this invention.

FPD is formed on the in-crystal centre (B area in a figure).

If this part is investigated, it can pull up, and speed can be mostly controlled within (+/-)0.02 [mm/min].

However, it turns out that the mean value of raising speed has become height entirely to a critical speed.

[0075]

(Example 3) Suppose that the mean value of raising speed is also controlled so.

OSF was made to become less than (+/-)0.01 [mm/min] to the mean value of the critical speed which disappears in a crystal bulk centre. That is, an impression magnetic field intensity is set to 4000G.

A response is enhanced the cycle of the feedback of a diameter control as 30 seconds from 60 conventional seconds.

It is made to suppress the fluctuation of a rate of crystal growth (raising speed) fully.

OSF becomes as follows the mean value of a crystal drawing speed less than (+/-)0.02 [mm/min] to the mean value of the critical speed which disappears in a crystal bulk centre, to the critical speed to which OSF disappears the raising speed of a crystal in a crystal bulk centre.
The crystal was pulled up less than (+/-)0.01 [mm/min], whilst controlling.

[0076]
The control result of the rate of crystal growth (raising speed) of the crystal stick which could be done, and the result of the defective generating situation in a crystal stick were shown in Figure 9. Figure 9 (a) is a figure as a result of a growth rate. Figure 9 (b) is a figure as a result of a crystal defect.

[0077]
If this result is observed, it will pull up by applying a magnetic field, and speed will be stabilised.
The mean value of the raising speed of a crystal is indicated that a control is performed so that it may become less than (+/-)0.01 [mm/min] to a critical speed mostly with the entire crystal stick.
Therefore, while OSF area was situated, the crystal, i.e., crystal centre section, of desired quality of this invention, the region (A area in a figure) used as that to which FPD and L/D do not exist in a crystal was able to obtain with the 1 entire single-crystal stick.

[0078]

(Example 4) Next, a half-moon type wafer is cut down from the region which is made into slivers in the above-mentioned Example, and has the quality of this invention among the D-shaped remaining single-crystal sticks. A mirror-surface process is applied to this and the mirror-surface wafer of a half-moon type silicon single crystal is produced. The grown-in defect was measured. Moreover, the heat oxidation treatment was applied and existence of OSF generating was confirmed. Furthermore, it investigated also about the oxide-film breakdown voltage characteristic.

[0079]

As a result, in the centre section of a wafer, OSF area with a diameter of about 20 mm or less exists.

However, the part of the outer side of the OSF area is a defect-free area where a grown-in defect does not exist.

The extremely low defect wafer to which N area was enlarged upper limit was obtained.

The area of this OSF area is about 1% or less of the area of the diameter wafer of 8 inches.

Few things can substantially influence as a reduction factor of a device yield.

Moreover, when tested by pulling up similarly in single crystals other than the diameter of 8 inches, it has confirmed that area of OSF area could be suppressed to the 5% or less of wafer area.

[0080]

The wafer in-plane oxygen density did not generate OSF by the heat oxidation treatment,

either, though especially OSF nucleus existed in OSF area of a centre section in the wafer 24 ppma or less, but the device yield had the excellent wafer whole surface.

[0081]

The oxide-film breakdown voltage characteristic of this wafer became in rate of 97-100 % of C-mode excellent article.

2 2

Moreover, C-mode measurement conditions are as follows.

1) Oxidation film thickness: 25 nm, 2) Measurement electrode: Phosphorus dope * polysilicon,

3) Electrode area: 8 mm2,

4) Judgement electricity: 1mA/cm-squared,

5) Excellent-article judging: That whose dielectric-breakdown electric field is 8MV/more than cm was judged to be an excellent article.

[0082]

Moreover, this invention is not limited to an above-mentioned embodiment.

An above-mentioned embodiment is an illustration. It has the same composition substantially with the technical thought described by the Claim(s) of this invention.

Even when the thing with the same effect is any kinds of thing, it is included by the technical range of this invention.

[0083]

For example, in the above-mentioned embodiment, when a silicon single crystal with a diameter of 8 inches was grown, the example was given and explained for every.

However, it is needless to say that this invention is not limited to this but it can apply also to the silicon single crystal of the diameter of 6 inches or less, 10-16 inches, or more.

[0084]

[EFFECT OF THE INVENTION]

As explained above, according to this invention, the control range of single-crystal-growth conditions becomes broad.

Although it has OSF area in the centre section, the wafer to which N area of OSF area outer side was enlarged upper limit is easily producible.

And, it can manufacture, maintaining high-production property and a high yield, since it is producible with the entire single-crystal stick.

Moreover, if low oxygen is also used together by the ability of able to suppress area of OSF area upwards small, OSF is not generated, either but a wafer whole surface can manufacture substantially a defect-free silicon-single-crystal wafer.

[BRIEF EXPLANATION OF DRAWINGS]

[FIGURE 1]

Let the direction position of a diameter of a silicon single crystal be a horizontal axis.

It is a many defects distribution figure at the time of making F/G value into a vertical axis.

[FIGURE 2]

It is an explanatory drawing showing the many defects distribution of the wafer of this invention quality in a crystal plane.

(a) When pulling up on usual raising conditions and it pulls up on the raising conditions of (b) this invention.

[FIGURE 3]

It is an explanatory drawing showing the many defects distribution in a crystal plane in the conventional method to pull up.

(a) When pulling up on usual raising conditions, and the precision control of the gradient was done and it is pulled up (b) raising speed and a crystal inside-temperature degree.

[FIGURE 4]

It is the explanatory drawing which showed the relation with a defective distribution in the raising speed in the conventional method to pull up, and the crystal plane.

(a) In the case of a high-speed pull-up, in the case of (b) medium-speed pull-up, it is in the case of (c) low-speed pull-up.

[FIGURE 5]

It is an explanatory drawing showing the boundary position of the generating area of OSF ring at the time of applying a heat oxidation treatment to a wafer and an OSF nucleus's existence area being influenced by the oxygen density during a crystal.

(a) In the graph showing the length direction position of a crystal stick, and the relation of an oxygen density, and (b) crystal longitudinal cross-section, it is the explanatory drawing

showing the boundary position of the generating area of OSF ring, and the potential area of OSF nucleus.

[FIGURE 6]

It is the schematic explanatory drawing of the single crystal drawing apparatus by the CZ process which was used with this invention.

[FIGURE 7]

It is a figure as a result of Example 1.

(a) It is a figure as a result of a growth rate.

(b) It is a figure as a result of a crystal defect.

[FIGURE 8]

It is a figure as a result of Example 2.

(a) It is a figure as a result of a growth rate.

(b) It is a figure as a result of a crystal defect.

[FIGURE 9]

It is a figure as a result of Example 3.

(a) It is a figure as a result of a growth rate.

(b) It is a figure as a result of a crystal defect.

[EXPLANATION OF DRAWING]

1... Growth Single-Crystal Stick,

2... Silicon Melt Solution,

3... Molten metal Surface Water,

4... Solid-liquid Boundary Surface,

5... Seed Crystal,

6... Seed Chuck,

7... Wire,

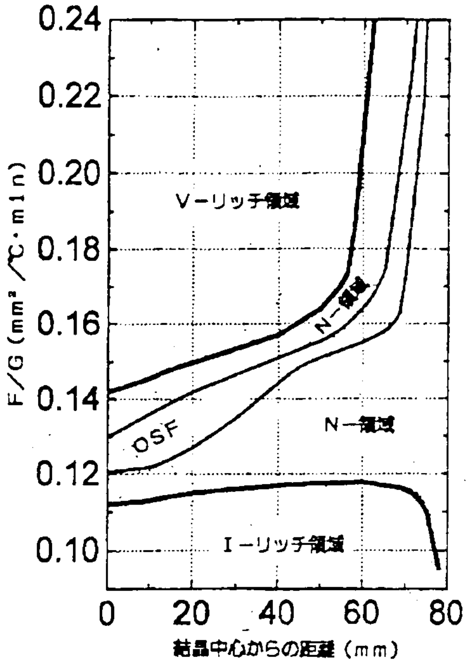
8... Solid-liquid Boundary-Surface Heat Insulating Material,

9... Upper-Part Surrounding Heat Insulating Material,

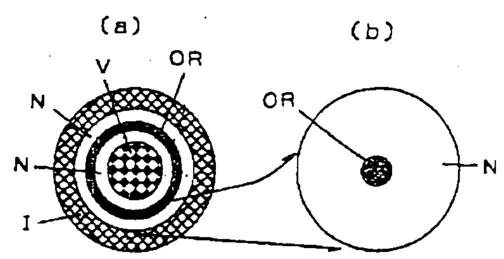
10... Gap between Molten metal Surface Water and Solid-liquid Boundary-Surface Heat-Insulating-Material Lower End,
30... Single Crystal Drawing Equipment,
31... Raising Chamber,
32... Crucible,
33... Crucible Hold Axis,
34... Heater,
35... Heat Insulating Material,
36... Cooling System,
37... Magnet.
V...V-rich area,
N...N-area,
I...I-rich area,
OR...OSF area.

[FIGURE 1]

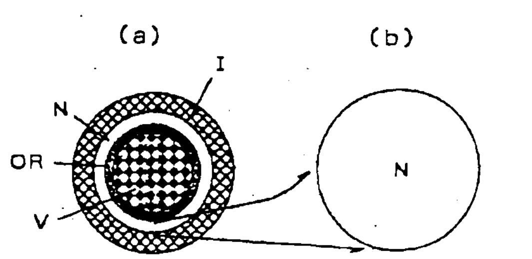
V-rich area
N area
N area
I-rich area
Distance (mm) from Core of Crystal



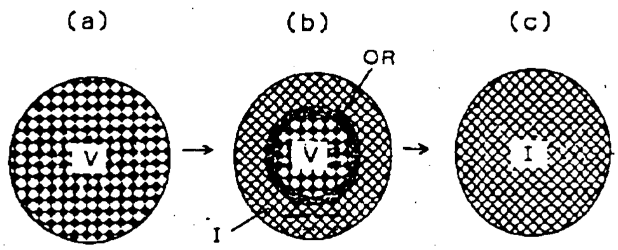
[FIGURE 2]



[FIGURE 3]

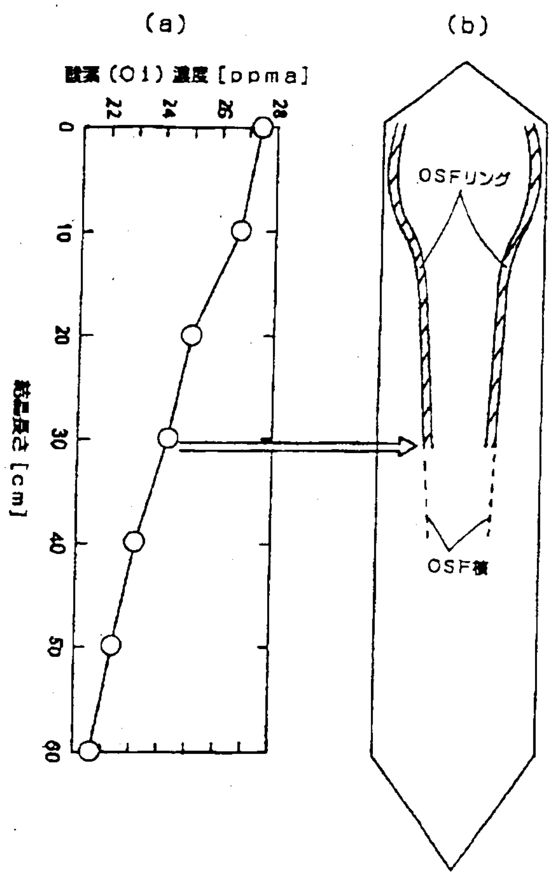


[FIGURE 4]

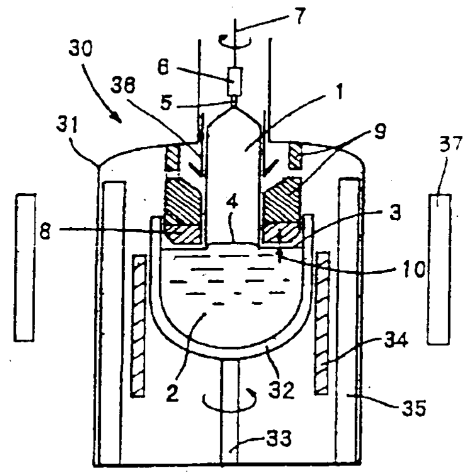


[FIGURE 5]

Concentration [ppma] of Oxygen (Oi)	OSF Ring
Length of Crystal [cm]	OSF Kernel

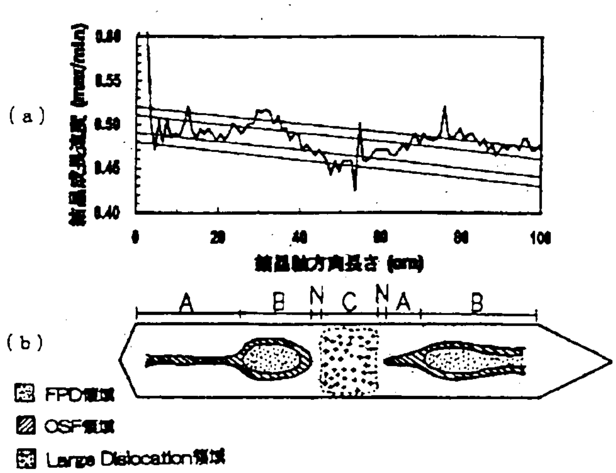


[FIGURE 6]



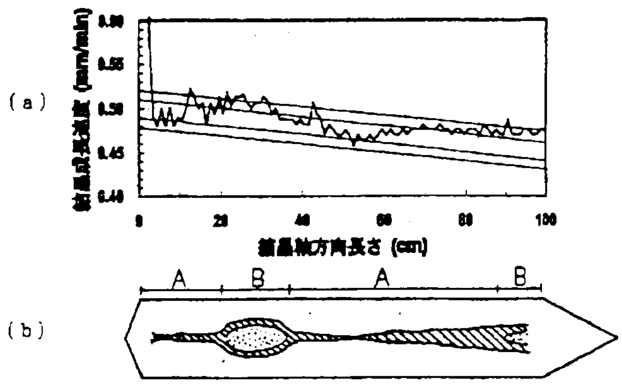
[FIGURE 7]

Speed of Crystal Growth (mm/min)
Length of Crystal Axial Direction (cm)
FPD area
OSF area
Large Dislocation area



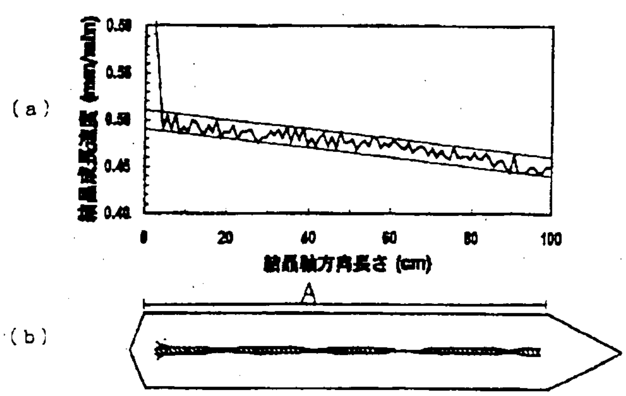
[FIGURE 8]

Speed of Crystal Growth (mm/min)
Length of Crystal Axial Direction (cm)



[FIGURE 9]

Speed of Crystal Growth (mm/min)	
Length of Crystal Axial Direction (cm)	



DERWENT TERMS AND CONDITIONS